INITIAL EFFECTS OF PRESCRIBED BURNING AND THINNING ON PLANT COMMUNITIES IN THE SOUTHEAST MISSOURI OZARKS

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Abstract—A study examining the effectiveness of prescribed fire and thinning as fuel reduction tools was initiated in the southeast Missouri Ozarks in 2001. Vegetation plots were established throughout 12 stands in each of 3 replicate blocks to monitor the effects of fire, thinning, and a combination of fire and thinning on the overstory, understory, and ground flora communities. The study was stratified across north facing slopes, south facing slopes, and ridge tops to discern the influence of topographic position on the treatments and on the resulting vegetation. Prior to treatment, overstory communities in all topographic positions were dominated by black oak (*Quercus velutina* Lam.) and white oak (*Q. alba* L.), and had relatively low diversity and evenness. Understory woody vegetation was dominated by red maple (*Acer rubrum* L.) on northern slopes, white oak (*Q. alba* L.) on ridges, and sassafras (*Sassafras albidum* [Nutt.] Nees) on southern slopes. Immediate and marked changes in the vegetative structure and species composition resulted from the initial burn, thinning, and combined treatments. Burning caused shifts in dominance by physiognomic group, with forbs, grasses, and sedges increasing, while woody tree, vine, and shrub species decreased. Thinning did not significantly affect physiognomic composition in the first year following treatment, and thinned plots were very similar to controls. Topographic position appeared to have more influence on ground flora composition than treatment in the first two years of the study. Continued monitoring may provide insight into the viability of using prescribed fire and thinning for ecosystem restoration in addition to fuel reduction.

INTRODUCTION

The Ozark Highlands region of southeast Missouri is an area of densely forested and rugged terrain. While pre-settlement forest conditions in the topographically variable Ozarks probably ranged from openings to completely closed canopies (Nigh 1992), many researchers believe the forests of the Ozark Highlands were predominantly open-canopy shortleaf pine (*Pinus echinata* Mill.) and oak (*Quercus* sp.) maintained by frequent low-intensity surface fires (Bielmann and Brenner 1951, Ladd 1991, Nelson 1997). Reconstructions of fire frequency in the upper Current River watershed, in the Ozark Highlands, indicated a mean fire interval (MFI) of 15.8 years for the period 1581-1700, 8.9 for 1700-1820, and 3.7 for 1820-1940 (Guyette and Dey 1997). After the establishment of national forests in the area and the enforcement of fire suppression policies, the MFI for Missouri is estimated to be 715 years (Westin 1992). While wildfires still occur in the Ozarks, the average area burned by each fire has been reduced at least 90 percent.

The history of logging in the Ozarks is similar to that seen elsewhere in the Central Hardwoods region. Much of the Ozarks was completely cutover in the late 19th century (Cunningham and Hauser 1989). The second-growth forests regenerated primarily from stump sprouting and are dominated by oak and hickory species. As a result, the shortleaf pine and oak-pine forest types in the Missouri Ozarks have been reduced from an estimated 6.6 million acres (Liming 1946) to approximately 400,000 acres (Cunningham and Hauser 1989). Consequently, fuels in the understory shifted from primarily pine litter and woody debris to hardwood litter and woody debris. Furthermore, litter accumulations and dense canopies have led to conditions unfavorable for the regeneration of oak and shortleaf pine (Stambaugh 2001).

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As the land becomes increasingly populated and fragmented and fuels accumulate, the risk of a devastating fire event increases exponentially (Guyette and others 2002). Though the Ozarks have a long history of periodic low-intensity surface fires, the accumulation of fuels over the past several decades reduces the predictability of fire behavior in these forests. Thus, there is a pressing need for information on potential fuel reduction methods for these forests, and a need for ecological evaluation of such methods to ensure long-term sustainability of the ecosystem. In 2001 a study was initiated in the Missouri Ozarks to investigate the potential of prescribed burning for fuel reduction in thinned and unthinned oak-hickory forests. The specific objective of the work presented here was to document initial effects of these treatments on the resident plant communities.

Study Area

The study area is located in the Black River Hills Oak-Pine Woodland/Forest Hills land type association (LTA) of the Current River Hills subsection of the Ozark Highlands section (Nigh and others 2000). The Black River Oak-Pine Woodland/Forest Hills LTA is characterized by hilly topography with steep slopes and occupies much of the Black River basin. Soils are mainly cherty, low-base soils associated with Roubidoux and Gasconade geologic formations (Nigh and Schroeder 2002). Two of the three study blocks are located in Clearwater Conservation Area, while another is located in Dickens Valley Conservation Area. Both areas are near Ellington, MO and managed by the Missouri Department of Conservation.

METHODS

Study Design and Site Selection

The study uses a split-plot experimental design. The variables include fire (2 levels), thinning (2 levels), and topographic position (3 types). The combinations of prescribed fire/thinning, prescribed fire/no thinning, no fire/thinning, and no fire/no thinning (control) were repeated across three topographic positions (protected backslope, ridge top, and exposed backslope) to form one study block. Control treatments were randomly located either on the east or west side of the block such that the prescribed fire treatment could be applied to the six burned plots as a single unit.

The study block design was replicated at three sites located within the Black River Hills LTA, with each block (replicate) containing 12 treatment plots. Stands were selected to represent mature, upland oak-hickory forests of the Missouri Ozarks. Stands chosen met the criteria of having a stand age of at least 50 years, an overstory dominated by oaks and hickories, and no evidence of fire or other major disturbance within the past 30 years. Three blocks of stands that met all of the criteria were identified, hereafter designated as Blocks 1, 2 and 3.

Fuel Reduction Treatments

Thinning operations were conducted using a mark-leave method during the growing season prior to the first burn. Stocking was reduced to ~40 square feet per acre (~3.7 m^2/ha). Preference for leave-trees was given to the most vigorous individuals of more fire tolerant species such as white oak, post oak (*Q. stellata* Wangenh.), and shortleaf pine. Non-commercial trees were felled by hand, and all slash was left on-site and broken down with chainsaws.

Prescribed burns were conducted by the Missouri Department of Conservation utilizing the ring fire method. The burns were conducted in spring 2003 before full leaf-out had occurred. One plot (Block 3, Ridge, Burn) that was to be treated with prescribed fire was not burned in 2003 due to time and weather constraints, and was dropped from first-year analyses. Flame lengths did not vary greatly between burn-only and burn-thin treatments except where slash piles occurred. Flame lengths varied from 0.5 to 1 foot in backing fires and 1 to 4 feet in head fires. At slash piles, flame lengths ranged from 5 to 40 feet, averaging between 10 and 15 feet (Kolaks and others 2004).

Vegetation Sampling

Permanent vegetation subplots were installed during the summer of 2001. Pre-treatment sampling was conducted May-August, 2001, and post-treatment sampling was conducted May-July, 2003. The size, shape, and configuration of each stand required a modified transect method for sampling three types of subplots: woody regeneration, overstory, and ground flora.

Woody regeneration subplots—Within each plot, 15 circular woody regeneration subplots (0.001 ha) were randomly located along a transect. Three of these subplots also serve as a plot center for 0.1 ha overstory subplots. In addition, five regeneration subplots were randomly placed within each 0.1 ha overstory subplot, for a total of 30 woody regeneration subplots per plot. All live woody stems <4 cm dbh rooted within these subplots were identified to species and tallied by 30 cm height classes. For multiple-stemmed woody species, each stem was tallied and height measured on only the tallest stem.

Overstory subplots—Within each 0.1 ha subplot, all live overstory trees greater than 4 cm dbh were identified to species, dbh measured, tagged, numbered, and location recorded. In post-treatment years, these tagged trees were assigned codes indicating mortality, root suckering, fire damage, and crown position characteristics.

Ground flora subplots—For the sampling of ground flora, one 1 m^2 quadrat was located in association with each of the 15 woody regeneration subplots established along the plot transect. Within each 0.1 ha overstory subplot, five additional 1 m^2 quadrats were also randomly located. Within each quadrat, all live herbaceous plants and woody regeneration (<4 cm dbh) rooted within the quadrat frame were identified to species and cover was estimated to the nearest 1 percent. Site characteristics were collected at each quadrat by measuring percent slope, aspect, and crown cover (densitometer reading), and estimating percentages of bare soil, leaf litter coverage, exposed rock, and downed dead woody material.

Statistical analyses—An ANOVA model was developed to include the three replicate sites, three aspect classes, and four levels of treatment. Using SAS, PROC GLM and PROC MIXED were used to test for differences between pre- and post-treatment plant community characteristics such as species richness (number of species per 30 m^2), diversity, and evenness. ANOVA was also used to analyze treatment effects on the proportional cover by physiognomic group, using an angular transformation to improve normality and homogeneity of variance (Beers and others 1966):

$$y = \sin^{-1} (\sqrt{x}) \tag{1}$$

Importance values (relative frequency + relative abundance) of individual species were used to examine which species increased or decreased greater than 10 percent following treatment, and also to determine new and missing species following treatment.

Diversity was calculated using the Shannon diversity index (Shannon and Weaver 1949, Magurran 1988):

$$H' = -\sum_{i=1}^{St} p_i \log_e p_i \tag{2}$$

Evenness was calculated using Pielou's formula (Pielou 1975):

$$J' = \frac{H'}{H'_{\max}} = \frac{H'}{\log_e S} \tag{3}$$

RESULTS

Overstory

Stand structure—Prior to treatment all study plots were fully stocked stands dominated by oak and hickory species. Across all plots, pre-treatment trees per acre (TPA) ranged from 241.6 to 485.8, with a mean of 357.4. Basal area (BA) ranged from 79.5 square foot per acre to 146.2 square foot per acre (7.4 to 13.7 m^2/ha), with a mean of 107.4 square foot per acre (10.0). Stands were on average 95 percent fully stocked with a range in stocking of 71.5 to 129.2 percent. In general, protected backslopes had the highest values for all three stand structure characteristics.

Thinning removed an average of 101.8 trees per acre and 57.7 square foot per acre BA, while stocking decreased an average of 59.1 percent. Burn-thin plots exhibited the greatest decreases in all three stand characteristics, followed by thin-only plots and burn-only plots. Although TPA, BA, and percent stocking decreased following treatment, burn-only plots were more similar to control plots following treatment than thin or burn-thin plots (table 1).

Species composition—Both before and after treatment, the composition of the overstory across all plots was dominated by the same species in terms of number of individuals: hickory sp. (*Carya* sp.), flowering dogwood (*Cornus florida* L.), white oak, black oak, and black gum (*Nyssa sylvatica* Marshall). In terms of relative BA, differences after treatment reflected the effect of thinning: shortleaf pine, scarlet oak (*Q. coccinea* Muenchh.), and post oak all had greater proportional abundance following thinning.

On protected slopes, hickory, dogwood, and black gum, represented much less of the proportional basal area following all treatments (when compared to pre-treatment levels), while scarlet oak, black oak, and white oak increased in mean relative basal area. On ridges and exposed slopes, similar patterns occurred, but with greater post oak and shortleaf pine presence in the post-treatment composition. The effect of thinning and/or burning on overstory species composition in the first year was primarily the reduction of small diameter dogwoods, black gums, and hickories.

Ground Flora

Species richness—Pre-treatment plot richness ranged from 20 to 91, with a mean of 36.5 species across all plots. Following treatment, mean plot richness was 36.8 and ranged from 20 to 87 species. The overall ANOVA model was not significant, and no significant differences in richness due to the main effects of treatment were found (table 2). Most of the variability in richness was due to differences among replicate blocks. Tests of the differences between least square means (LSMeans) indicated a significantly higher richness on exposed slopes than protected slopes following treatment (P=0.0437).

Table 1—Mean trees per acre (TPA), basal area (BA), and percent stocking by site, aspect, and treatment

Site, aspect, and treatment	Pre-treatment 2001			Post-treatment 2003			Percent change between years		
	TPA	BA	Stocking	TPA	BA	Stocking	TPA	BA	Stocking
		ft^2/ac	*percent*		*ft^2/ac*	*percent*		*ft^2/ac*	*percent*
Site 1	341	105	92	187	77	65	-45	-26	-29
Site 2	380	109	99	174	70	61	-54	-36	-38
Site 3	351	108	95	208	78	67	-41	-27	-29
Protected	367.4	110.4	96.8	184.1	76.2	64.4	-50	-31	-33
Ridge	348.9	105.8	94.1	188.3	75.8	65.1	-46	-28	-31
Exposed	356.1	105.9	94.2	196.2	73.6	63.9	-45	-31	-32
Control	350.6	107.3	94.7	329.0	107.9	94.4	-6	1	-0
Burn	333.2	94.3	84.7	246.9	89.3	77.5	-26	-5	-9
Harvest	338.3	112.3	97.3	94.7	54.0	44.9	-72	-52	-54
Harvest-burn	370.7	105.1	94.1	60.0	39.7	32.5	-84	-62	-65

Table 2—Results of analysis of variance tests conducted for post-treatment ground flora plant community characteristics, including analysis of difference scores (post-treatment minus pre-treatment)

	P-value									
Post-treatment	Overall	Site	Aspect	Harvest	Aspect x harvest	Burn	Aspect x burn	Harvest x burn	Aspect x harvest x burn	Site x aspect	Significant differences[abcd]
Richness (n = 34)	0.1053	0.0268								0.0462	None
Abundance (n = 35)	<.0001			0.0001		<.0001		0.0001			**ab ac ad af ag ah aj ak al bc be** bg **bi** ce ch **ci cj** cl **de di ef eg eh ej ek el fi** gh **gi** gj gl **hi ij ik il**
Diversity (n = 34)	0.0028		0.0049			0.0008	0.0146			0.0107	**ab ad ae af ag ah ai aj ak al bc cd** ce **cf cg ch** ci **cj** ck **cl**
Evenness (n = 35)	0.0259		0.0284			0.0024	0.0253				**ab ad** ae af **ag ah ai** aj ak **al** bc **cd** cg **ch** ci **cl** el jl kl
Differences											
Richness (n = 35)	0.3352	0.0129									cj
Abundance (n = 35)	0.0007	0.0439	0.0248	0.003		0.0002		0.0002			**ab ac ad af** ag **ah** aj ak **al be** bg **bi** bj bk **ce** cg ch **ci** cj ck **de di ef** eg eh ej ek **el fi** gi **hi** ij ik **il**
Diversity (n = 35)	0.1114					0.0024					ab ad al bc be bi bj bk cd **cl** de dg di dj dk el gl il jl kl
Evenness (n = 35)	0.1206					0.0074					ab ad **al** bc be bg bi **bj** bk cl di dj el fl gl il **jl** kl

[a] All letter combinations imply a significant difference between aspect and treatment combinations as follows: a = protected, control; b = protected, burn; c = protected, thin; d = protected burn-thin; e = ridge, control; f = ridge, burn; g = ridge, thin; h = ridge, burn-thin; i = exposed, control; j = exposed, burn; k = exposed, thin; l = exposed, burn-thin.
[b] Letters in bold indicate significance at the 0.01 level, all others significant at the 0.05 level.
[c] Only significant sources of type III SS in the model are indicated.
[d] Significant differences based on tests of least square means for effect aspect x harvest x burn Pr>|t| for H0: LSMean(i) = LSMean(j).

Diversity and evenness—Prior to treatment, diversity values ranged from 2.0 to 3.5 (mean = 2.5). Pre-treatment diversity differed significantly by block and aspect. While not significantly different from each other, ridges and exposed slopes tended to have higher mean diversity than protected slopes. Following treatment, diversity values ranged from 2.1 to 3.5 (mean = 2.6. Significant variability in diversity existed due primarily to the effects of burning (P=0.0008) and aspect (P=0.0049) (table 2). Mean diversity was highest on burn-thin plots, followed by burn plots, thin plots, and controls. Mean diversity scores on protected control and protected thin plots were significantly lower than those of all other aspect and treatment combinations.

LSMeans tests of differences showed significantly greater increases in diversity on protected plots versus ridge plots (P=0.0280). The highest increases in diversity occurred on burn-thin plots in all landscape positions, followed by burned plots, controls, and thinned plots.

Evenness (J') differed significantly before treatment among the three aspect classes. Mean evenness on protected plots was significantly lower than on ridge (P=0.0308) and exposed (P=0.0244) plots prior to treatment. A comparison of the LSMeans also indicated that exposed plots with a burn-thin prescription had significantly lower evenness prior to treatment than exposed control plots (P=0.0109) and exposed burn-only plots (P=0.0145).

Following treatment, burned plots had significantly higher mean evenness than unburned plots (P=0.0024). Mean evenness on burn-thin plots was significantly higher than those on control (P=0.0015) and thin (P=0.0029) plots. Mean evenness increased across all aspects, with evenness increasing more substantially on protected slopes. Mean evenness increased the most on burn-thin plots, followed by burn-only, thin-only, and controls. Only thin and burn-thin plots were significantly different than controls in mean evenness following treatment.

Species responses—The burn-only and burn-thin treatments tended to increase the abundance of *Carex* sp. and *Panicum* sp.; both genera increased by at least 10 percent in mean importance value on all aspects with these treatments, though their overall relative abundance remained small. *Desmodium*, the most ubiquitous herbaceous genera prior to treatment, was generally reduced by burning, with the exception of ridge burn plots. Scarlet oak seedlings were eliminated entirely following treatment on burn plots on all landscape positions, and on burn-thin plots in protected positions.

In the post-treatment sample, three species occurred despite being absent prior to treatment: *Ambrosia artemisifolia* (ragweed), *Erechtites hieracium* (fireweed) and *Phytolacca americana* (pokeweed). All are weedy annual forbs commonly found in Missouri on recently disturbed sites, and were found only on treated plots in this study. There were no annual forbs found in the pre-treatment sample.

In general, burning affected the cover and frequency of woody species in the ground flora layer more than herbaceous species, increasing sassafras and sumac species while decreasing scarlet oak, American hazel (*Corylus americana* Walt.), Carolina buckthorn *(Rhamnus caroliniana* Walt.), white oak, eastern redbud (*Cercis canadensis* L.), flowering dogwood, black gum, red maple, black oak, bush honeysuckle (*Lonicera flava* Sims.), Virginia creeper (*Parthenocissus quinquefolia* L.), persimmon (*Diospyros virginiana* L.), and *Vaccinium* sp. These species responded similarly to both the burn-only and burn-thin treatments. Thin-only plots exhibited increases in woody species such as black gum, *Vaccinium* sp., *Vitis* sp., flowering dogwood, and Virginia creeper, and decreased cover and frequency of sassafras, red maple, black oak, white oak, and persimmon.

Compositional changes—Ground flora species were grouped physiognomically: perennial native forbs (including herbaceous vines and ferns), annual native forbs, graminoids (grasses and sedges), legumes, woody tree species, woody vines, and shrubs. Proportional abundance of each physiognomic group was examined for each aspect and treatment through mean relative cover, and LSMeans tests revealed statistical differences between pre- and post-treatment ground flora physiognomic composition.

Regenerating tree species decreased in burn-only plots in all landscape positions, and woody vines, graminoids, perennial forbs, and annual forbs increased following treatment. Shrub abundance decreased substantially on ridges, decreased slightly on exposed slopes, and increased slightly on protected slopes. Legumes increased substantially on ridges (fig. 1), decreased slightly on exposed slopes (fig. 2), and remained stable on protected slopes (fig. 3).

Slight decreases in abundance of regenerating tree species, very slight decreases in shrubs, and slight increases in woody vines occurred in thin-only plots in all landscape positions exhibited. In general, physiognomic composition did not shift as dramatically in thin-only plots following treatment as burned plots, and thinned plots were more similar to controls than to other treatments.

Burn-thin plots in all landscape positions showed decreased proportional abundance of regenerating tree species and legumes, and increased abundance of graminoids, perennial forbs, and annual forbs following treatment. Woody vines increased substantially on exposed slopes, increased slightly on protected slopes, and decreased slightly on ridges. Shrubs increased slightly on protected slopes, decreased on exposed slopes, and remained stable on ridges.

SUMMARY AND CONCLUSIONS

All fuel reduction treatments significantly reduced ground flora abundance on every landscape position. Landscape position did seem to mitigate some of the effects of treatment, as ridges were generally less affected by the treatments than both protected and exposed slopes. Thinning consistently impacted the ground flora layer less than the burn and burn-thin treatments in terms of species composition. Annual forbs such as fireweed and pokeweed were prolific on burn-only and burn-thin plots across all aspects. Diversity increased more on protected slopes with these treatments than on any other aspect-treatment

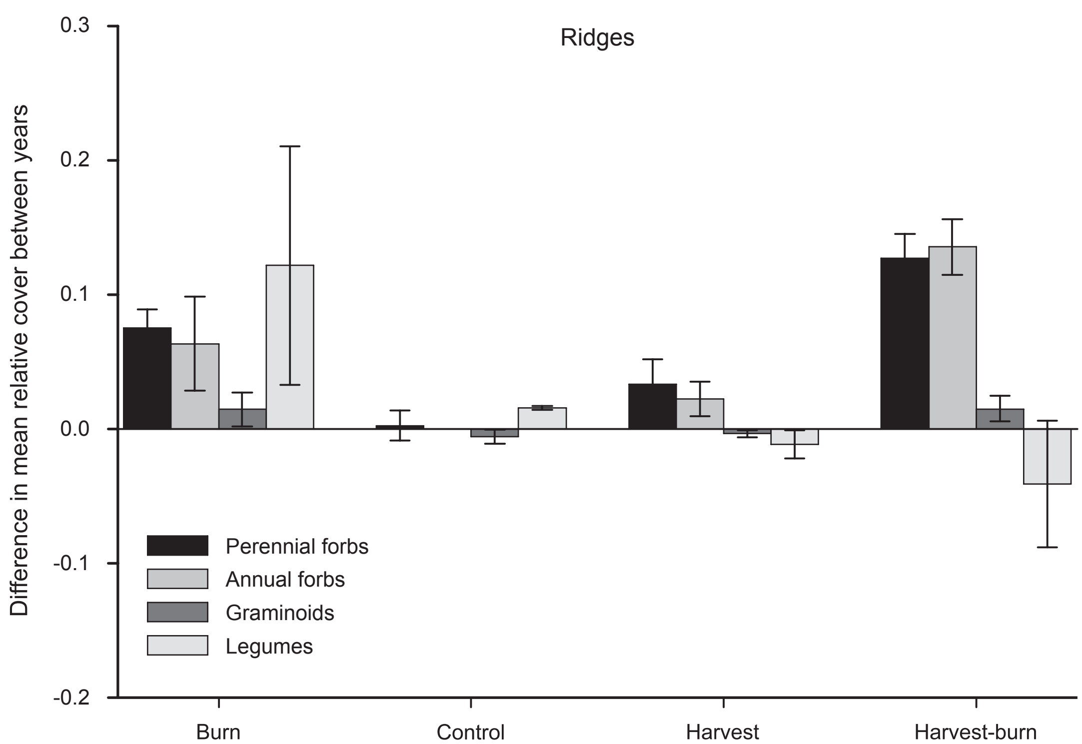

Figure 1—Differences in mean relative cover (post-pre) of herbaceous physiognomic groups on ridges, by treatment.

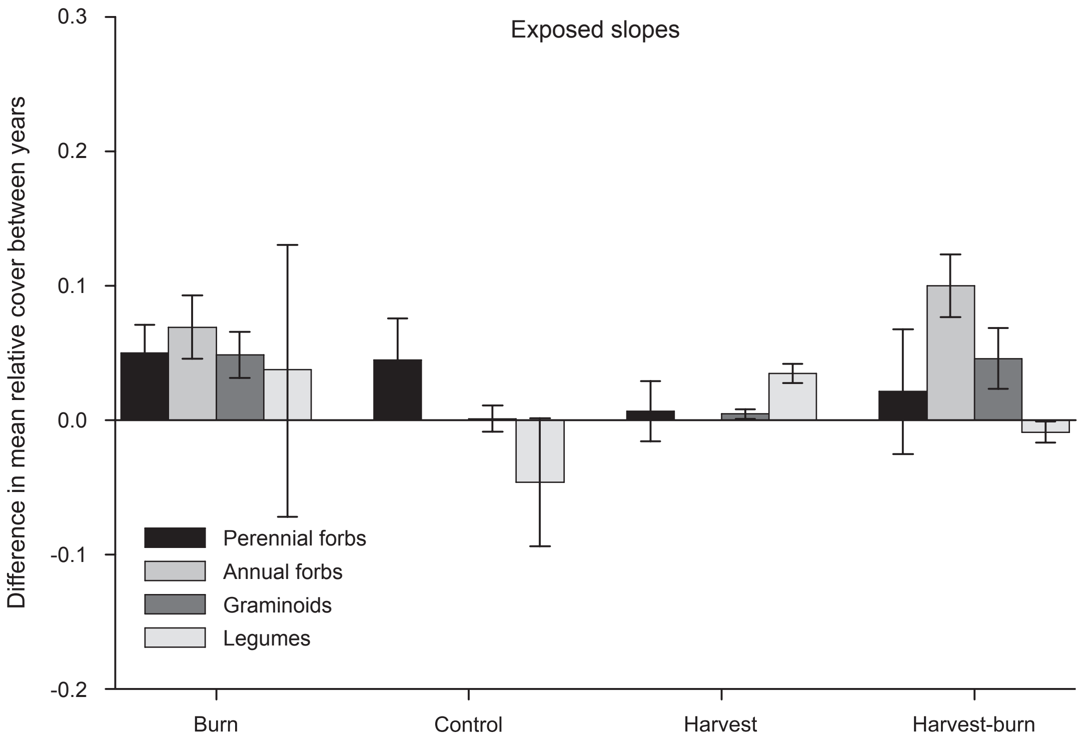

Figure 2—Differences in mean relative cover (post-pre) of herbaceous physiognomic groups on exposed slopes, by treatment.

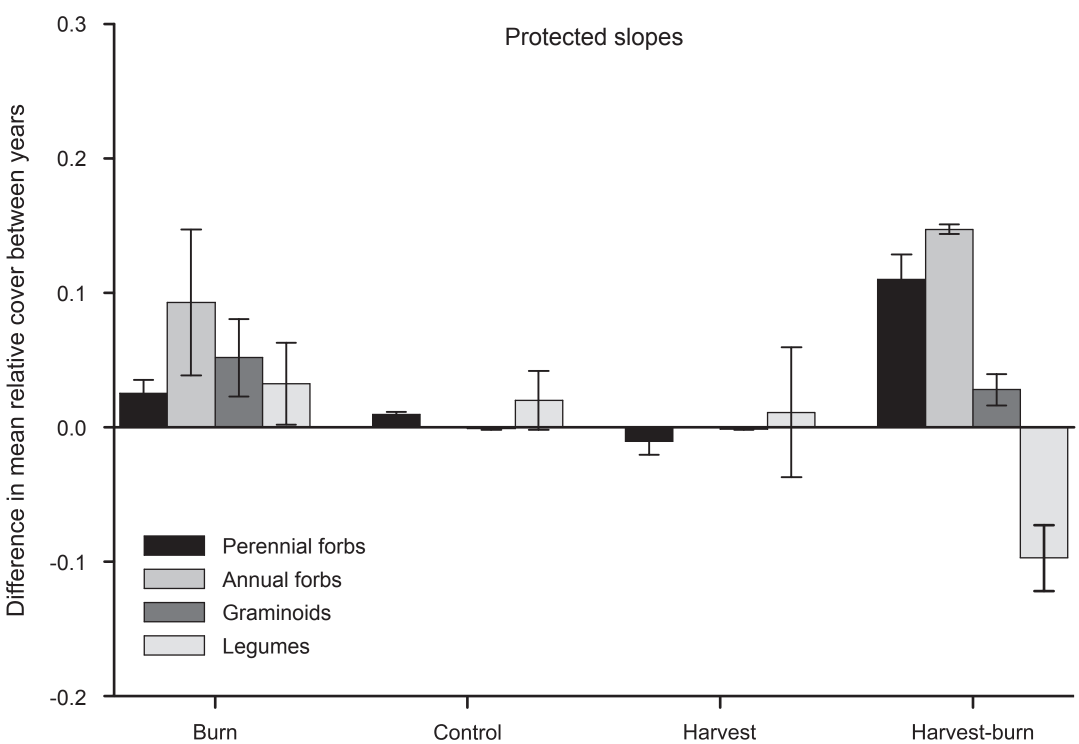

Figure 3—Differences in mean relative cover (post-pre) of herbaceous physiognomic groups on protected slopes, by treatment.

combination. Legumes increased the most on burn-only plots, while they decreased the most on burn-thin plots. It is important to note that these findings may be very short-lived, and may capture only the immediate response to these treatments.

The study is scheduled to continue until at least 2007, and a second prescribed burn and vegetation sampling was conducted in 2005. Monitoring of the herbaceous plots will continue, and vegetation data will continue to be linked with fire behavior and fuel loading data as the plots continue to change following treatments. In addition, woody regeneration and overstory plots will provide information on overstory mortality and regenerative capacity following these treatments.

Implications for findings thus far suggest there is a substantial interaction among all treatment types with topographic position. Careful consideration of treatments, particularly those utilizing prescribed fire, must consider topographic position.

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